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Sampling of the Mackinaw River in Central Illinois for Physicochemical and Bacterial Indicators of Pollution

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ABSTRACT

Water samples taken from selected sites along the Mackinaw River in Central Illinois were subjected to physicochemical and microbiological analyses to indicate pollution levels in the River. Seventeen sites were identified as possible sources of pollution from point sources (e.g., untreated "wildcat" sewer discharge) and non-point sources (e.g., agricultural runoff) by the Illinois Environmental Protection Agency (IEPA) and The Nature Conservancy. Physicochemical parameters for which water samples were analyzed included temperature, pH, conductivity, turbidity, and dissolved oxygen (DO). Water samples were analyzed for bacteria routinely used as indicators of fecal pollution in both drinking water and wastewater (fecal coliform and fecal Streptococci). Results of physicochemical analyses were found to be within acceptable ranges for natural surface waters as described in the literature. However, concentrations of fecal coliform exceeding recommendations for natural surface waters were recovered from samples taken from eleven of seventeen sites tested.

INTRODUCTION

The quality of surface and ground water is important both nationally (U.S. Environmental Protection Agency - USEPA, 1996) and regionally in Central Illinois (Illinois Environmental Protection Agency - IEPA, 1994; 1995; 1996; Short, 1988). Water from the Mackinaw River and its tributaries is used for a variety of purposes in Central Illinois, including drinking, recreation, agriculture, and industry. Protection of quality water supplies is important for future generations. However, water quality is impacted by many water use sectors, including contamination from agricultural runoff, residential and municipal sewage effluent, and industrial wastes (USEPA, 1994; IEPA, 1994; 1995; 1996). The Mackinaw River has been identified as one of the highest quality rivers in Illinois by the IEPA (1996). Both state and private agencies are attempting to maintain

the high quality of this river by limiting or remediating pollution (IEPA, 1995; The Nature Conservancy, 1995).

The Mackinaw River Watershed is located in Central Illinois (Figure 1). The primary land use in the watershed is agriculture. Agricultural practices impact the watershed through runoff of fertilizer, pesticide residue, and erosion. Residential development also impacts the watershed, particularly around Lake Bloomington, which, along with Lake Evergreen, is the drinking water supply for the City of Bloomington, IL. Residential, commercial, and agricultural development have been limited around Lake Evergreen in an effort to limit pollution (IEPA, 1996, Farrel, et al., 1995). Three main tributaries contributing to the Mackinaw River are Panther Creek, Money Creek, and Six Mile Creek. Panther Creek contributes to the Mackinaw from the Northwestern part of the watershed. Little Panther Creek and the East and West Branches of Panther Creek contribute to Panther Creek. Tributaries contributing to the Mackinaw River in the Northeastern portion of the watershed include Buck, Patton, and Henline Creeks. Money Creek and Six Mile Creek are the major tributaries contributing to Lake Bloomington and Lake Evergreen, respectively, which contribute to the Mackinaw River from the Southern part of the watershed. Crooked and Little Crooked Creek contribute to the Mackinaw East of Money Creek while Denman Creek contributes to the Mackinaw West of Six Mile Creek. All of these tributaries contribute to the Mackinaw River above the Westernmost (downstream) sampling point in this study (Figure 1).

While federal, state, and local governmental agencies and private agencies monitor water quality periodically, the extent and type of this monitoring may be inadequate to determine many potential environmental health effects that may impact detrimentally upon human health and the delicate balance of ecosystems (USEPA, 1994; IEPA, 1994; 1995; 1996). Water quality in the Mackinaw River has previously been studied by measuring physicochemical indicators of pollution and macroinvertebrate populations (e.g., aquatic insects, mussels, etc.) affected by pollution (Short, 1988), but microbiological testing has not been a major focus. Microbiological analyses of water are routinely used to determine levels of microorganisms that are indicative of fecal contamination (e.g., from human sewage effluent or other animal wastes). Coliform bacteria indicate the potential presence of other pathogenic microorganisms capable of causing disease if ingested in sufficient quantities. Therefore, if coliform are present in water above required or recommended levels, the water is assumed more likely to transmit infectious disease to humans or other animals (Eaton, 1995; Salvato, 1992).

The potential for transfer of potentially pathogenic microorganisms, nutrients, and toxic chemicals from agricultural, residential, and industrial wastes through soil to surface water or groundwater is a legitimate environmental health concern (Kelley, 1991; 1994; 1995). Sampling and characterization of local surface water systems is also a teaching and learning tool to introduce students to important environmental health concepts, such as how water systems respond to various contaminants, and how pollution may be reduced (Kelley, 1994; National Science Foundation - NSF, 1993).

This study was a component of The Nature Conservancy Mackinaw River Project. The goal of the Mackinaw River Project is to develop a workable plan to ensure the protection of the Mackinaw River and its water quality through voluntary efforts to reduce or

eliminate runoff and wastes that currently enter the river. Constructed wetlands have been proposed as a technique for wastewater treatment to economically remediate point- and non-point source river pollution. The Nature Conservancy is currently seeking funding for constructed wetland projects to remediate point and non-point source pollution of the Mackinaw River (The Nature Conservancy, 1995).

The primary objective of this study was to determine concentrations of microbiological indicators of pollution in surface waters in the Mackinaw River and its tributaries. These data can indicate sources of both point and non-point sources of fecal pollution that may be adversely impacting water quality in the region (Farrel, 1995). This information may also be used to reduce or eliminate sources of pollution.

A secondary objective of this study was to monitor basic physicochemical parameters of water in the Mackinaw River (temperature, pH, conductivity, turbidity, and dissolved oxygen levels) and relate these parameters to general water quality in the river. These data also indicate potential sources of point and non-point pollution in the region from agricultural, industrial, and residential sources.

A third and final objective of this study was to supplement the work of local, state, and federal agencies monitoring water quality in the region. Data generated from this study will contribute to the community by providing more precise information concerning water quality than is currently available. Data generated from this study is being shared through publications and presentations to promote increased understanding and potential remediation of regional water pollution.

MATERIALS AND METHODS

Physicochemical Analyses

Temperature and conductivity measurements were made on-site from June-September, 1996 using a YSI Model 33 Conductivity Meter (Yellow Springs Instruments, Yellow Springs, OH). pH measurements were also taken on-site using a Hach Comparator (Hach Company, Loveland, CO). Dissolved oxygen (DO) measurements were taken using a YSI Model 54A Dissolved Oxygen Meter (Yellow Springs Instruments, Yellow Springs, OH). Turbidity measurements were made using a Hach DR2000 Spectrophotometer (Hach Company, Loveland, CO). Methods used for physicochemical water analyses were performed as described in Standard Methods for the Examination of Water and Wastewater, 19th Ed. (1995), or Hach Water Analysis Handbook, 2nd Ed. (1992). Fourteen sites along the Mackinaw were initially identified by the Illinois Environmental Protection Agency and The Nature Conservancy as potential areas contributing to pollution of the Mackinaw River (Table 1). Sampling sites on public property were chosen adjacent to bridges to avoid obtaining permission to access private property. Replicate samples were taken from (or replicate on-site analyses made at) each site, one on each side of the bridge. These sites were sampled from June 3-24, 1996. Three additional sites of interest were later identified by The Nature Conservancy and sampled on September 9, 1996. All sites were sampled in replicate except for samples 6-9, which were sampled four times each.

Microbiological analyses

Water samples of approximately 500 ml were taken from 17 selected sites (Figure 1, Table 1) using aseptic technique and stored in sterile Whirlpak® - type sealed plastic bags according to collection and storage procedures outlined in Standard Methods for the Examination of Water and Wastewater, 19th Ed. (1995). Duplicate microbial analyses of each collected sample were performed for each site. Sites # 6-9 were re-sampled in duplicate two weeks following the initial sampling. Therefore, n = 2 (n = 4 for microbial analyses) for sites 1-5 and 10-17, and n = 4 (n = 8 for microbial analyses) for sites 6-9. Appropriate volumes of undiluted water samples or appropriate dilutions of water samples were filtered through 0.45-μm pore size 47-mm diameter gridded filters (Micron Separations Inc., Westborough, MA) using a Nalgene® (Nalgene Co., Rochester, NY) filtration apparatus attached to a vacuum pump. Filters were transferred to the surface of appropriate media (M-FC for fecal coliform and m Enterococcus for fecal Streptococci) in 50-mm petri dishes and incubated (Dry-type Bacteriological Incubators, Blue M Electric Company, Blue Island, IL) for culturing of bacterial groups. M FC media was incubated at 44.5° C for 24 hrs, and m Enterococcus media at 35° C for 48 hrs. Transfers to confirmatory media were made for microbial groups when required (Eaton, 1995). Aseptic technique was observed during all microbiological analyses. Characteristic colonies were counted and bacterial group concentrations reported on a Colony Forming Unit per 100-milliliter basis (CFU/100 ml).

Bacterial culturing techniques used in determining bacterial group concentrations in water samples were as described in Standard Methods for the Examination of Water and Wastewater, 19th Edition (1994) with modifications as specified above using prepared dehydrated culture media (Difco Laboratories, Detroit, MI).

RESULTS

Physicochemical analyses

Mean data for physicochemical and microbiological analyses of water samples are reported in Table 2. Temperature of water at sampling sites ranged from 12.5° C to 26° C. Levels of pH of water at sampling sites ranged from 7.1 to 8.0, within the range of natural waters of 6.0 to 9.0 indicated by Salvato (1992). Conductivity of water at sampling sites ranged from 310 to 800 μMhos, within the normal range of potable water of 50 to 1500 μMhos (Eaton, 1995). Turbidity of water samples varied from 3.0 FTU (Formazin Turbidity Units) to 125 FTU. An unusually high turbidity level was found at site 15 (125 FTU), possibly due to suspension of sediment during sampling. Turbidity in a majority of samples (37/42 total samples analyzed) was below 50 FTU. Dissolved oxygen levels in water samples ranged from 7.1 to 9.4, above minimum levels of 5.0 mg/l required to support fish survival and reproduction (Salvato, 1992).

Microbiological analyses

Fecal coliform concentrations ranged from this study's detection limit of less than 10 CFU/100 ml to 230,000 CFU/100 ml. Fecal Streptococci concentrations ranged from 800 to 16,000 CFU/100 ml. Highest concentrations of fecal coliform were found at site # 7. Highest concentrations of fecal Streptococci were found at site #1. A ranking of sites sampled for which mean fecal coliform concentrations exceeded 2,000 CFU/100 ml (from highest to lowest concentration) are as follows: Site #7, 1, 12, 6, 14, 11, 15, 9, and

13 (Table 2). High variability of some microbial concentration data was primarily due to variation between or among different samples (e.g., taken at different locations or different times), rather than variability of microbial concentrations within the same sample.

DISCUSSION

Physicochemical analyses

Results of physicochemical analyses of water samples, including temperature, pH, conductivity, turbidity, and dissolved oxygen are within ranges of natural waters indicated in the literature (Eaton, 1995; Salvato, 1992). A high variability in turbidity was found among sampling sites, which may have been due to localized suspension of sediment, possibly caused by animals (e.g., cattle walking in river), runoff, or erosion discharge from drain tiles.

Microbiological analyses

Salvato (1992) and the Federal Water Pollution Control Administration (FWPCA, 1968) have suggested that acceptable levels of fecal coliform concentrations for general recreational use waters for which ingestion is not a significant concern should not exceed an average of 2,000 CFU/100 ml. Samples taken from sites #1, 6, 7, 8, 9, 11, 12, 13, 14, 15, and 17 were above recommended levels of 2,000 CFU/100 ml fecal coliform (11/17 sites tested). There does not appear to be an unusual distribution of these sites (e.g., clustering near a specific geographic area). However, most of the sites chosen were near small townships that have little or no wastewater treatment prior to effluent discharge. Therefore, untreated waste from these townships may have contributed to fecal coliform and fecal Streptococci recovered from the Mackinaw River. Other possible sources of fecal pollution include runoff of animal waste (e.g., cattle, pigs, goats, etc.) from agricultural practices, as well wild animal waste (e.g., ducks, geese, raccoons, etc.)

Concentrations of these fecal coliform indicator bacteria suggest that disease-causing microorganisms (pathogens) may also be present in water samples in concentrations high enough to cause health concerns for persons exposed to these waters even if there is not a significant risk of ingestion of the water (Salvato, 1992, FWPCA, 1968).

Correlation of results to streamflow and precipitation data

No apparent correlation was found between physicochemical and microbiological data generated and streamflow or precipitation data generated during the sampling periods (U.S. Geological Survey, 1996). In other words, whether stream flow and precipitation levels were high or low, widely ranging concentrations of bacterial indicators were recovered from different sampling sites, while physicochemical data remained fairly constant. However, no statistical analysis was performed to confirm these observations. Point-source pollution from residential human wastes (e.g., “wildcat” sewers) would be expected to be fairly consistent in volume and strength, while non-point source pollution would be expected to increase in volume with runoff of rainfall. Therefore, increased streamflow would be expected to dilute point-source pollution and generally reduce the concentration of indicator microorganisms, while increased streamflow from precipitation would be expected to generally increase the concentration of indicator microorganisms from animal wastes carried by rainfall runoff. The lack of apparent

correlation of streamflow data and microbiological or physicochemical indicators suggests that pollution sources were a combination of point- and non-point.

Conclusions

Physicochemical parameter analyses of water samples yielded results within expected ranges for natural waters. Physicochemical analysis results suggested that the Mackinaw River maintains the physical and chemical capacity to remediate most biodegradable organic pollution at current levels. Fecal coliform concentrations above recommended levels for recreational surface waters were recovered from 11 of 17 sites tested. Results of bacterial analyses suggested that there might be an increased risk of transmission of infectious disease due to water pollution from animal waste sources in the Mackinaw River in those areas for which samples indicated fecal coliform levels exceeding 2,000 CFU/100 ml.

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Table 1: Geographic locations of sampling sites on the Mackinaw River shown in Figure 1 (adjacent to bridges). *Note: names of townships or cities are used only for geographic reference.*

Site #1: Sibley Ditch on Route 47 (Ford County – West of Sibley).
Site #2: Mackinaw River on 3700 East (McLean County – Southwest of Anchor).
Site #3: Mackinaw River on 1900 North (McLean County – South of Colfax).
Site #4: Mackinaw River on 3275 East (McLean County – West of Colfax).
Site #5: Mackinaw tributary on 1800 North (McLean County – East of Cooksville).
Site #6: Money Creek on 2000 North (McLean County – Northeast of Towanda).
Site #7: Mackinaw River on Pine Street (McLean County – South of Lexington).
Site #8: Turkey Creek on Route 66 (McLean County – North of Lexington).
Site #9: Turkey Creek on 2475 North (McLean County – Northwest of Lexington).
Site #10: Mackinaw River on Gunner's Trace Road (McLean County – Southwest of Lexington).
Site #11: West Branch of Panther Creek on 2700 East (Woodford County – South of Minonk) *Note: Minonk township is not in the Mackinaw River Watershed.*
Site #12: West Branch of Panther Creek on County Road 4 (Woodford County – Southeast of Roanoke).
Site #13: Mackinaw River on Route 150 (Woodford County – West of Congerville).
Site #14: Hudson Creek on Route 51 (McLean County – West of Hudson).
Site #15: Panther Creek on Route 24 (Woodford County – Southeast of Secor).
Site #16: Mackinaw River on Interstate 39 (McLean County – Northwest of Evergreen Lake).
Site #17: Mackinaw River on Highway 29 (McLean County – Northeast of Bloomington Lake).

Figure 1: Sampling sites on the Mackinaw River.

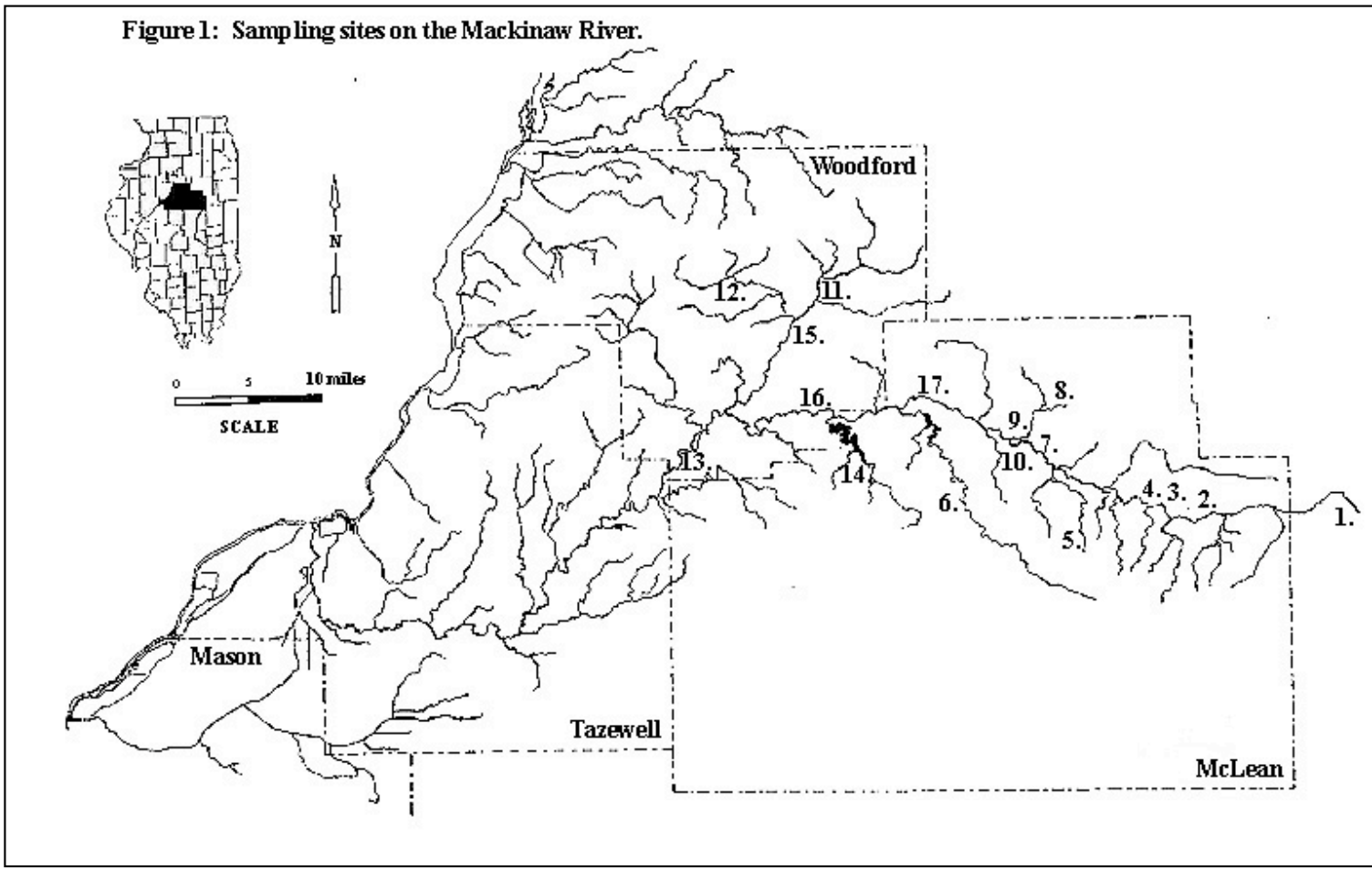

Table 2 - Results of physicochemical and microbiological analyses of Mackinaw River water samples

Site #	Temperature (C°)	pH	Conductivity (μMhos)	Turbidity (FTU)	Dissolved Oxygen (mg/L)	Fecal Coliform (CFU/100 ml) $\mu \pm \sigma$ [a]	Fecal Streptococci (CFU/100 ml) $\mu \pm \sigma$ [a]
1	13.8 ± 0.3	7.2 ± 0.05	349.0 ± 39.0	70.0 ± 6.0	ND[b]	13,700 ± 6,400	9,500 ± 6,200
2	13.2 ± 0.4	7.4 ± 0	434.0 ± 4.0	29.5 ± 5.5	7.6 ± 0.5	200 ± 100	5,000 ± 300
3	14.3 ± 0.3	7.5 ± 0	442.5 ± 0.5	36.5 ± 0.5	8.1 ± 0.05	200 ± 100	3,100 ± 500
4	14.5 ± 0.5	7.5 ± 0	455.0 ± 5.0	49.0 ± 1	8.1 ± 0.1	200 ± 122	5,700 ± 2,600
5	14.3 ± 0.8	7.4 ± 0.3	453.0 ± 13.0	12.0 ± 4.0	7.5 ± 0.2	300 ± 178	1,700 ± 690
6	17.3 ± 3.3	7.7 ± 0.1	548.0 ± 63.8	24.3 ± 7.0	9.0 ± 0.5	5,350 ± 6,200	4,800 ± 1,690
7	13.8 ± 1.2	7.2 ± 0.1	581.0 ± 81.7	3.0 ± 0.1	8.5 ± 0.2	98,300 ± 95,200	6,900 ± 2,710
8	15.6 ± 1.5	7.4 ± 0.04	523.0 ± 55.0	9.3 ± 1.3	8.8 ± 0	1,410 ± 730	2,530 ± 820
9	15.4 ± 2.8	7.6 ± 0.1	545.0 ± 45.5	31.5 ± 32.0	8.7 ± 0.2	3,390 ± 3,960	2,140 ± 1,470
10	14.1 ± 0.1	7.8 ± 0.1	506.0 ± 14.0	26.0 ± 0.5	8.3 ± 0	700 ± 460	2,930 ± 535
11	20.0 ± 0	7.8 ± 0.1	600.0 ± 0	19.5 ± 3.5	8.0 ± 0.2	3,850 ± 512	4,400 ± 1,250
12	17.0 ± 0	7.7 ± 0	650.0 ± 0	14.5 ± 0.5	8.4 ± 0.1	8,100 ± 1,660	5,780 ± 800
13	26.0 ± 0	8.0 ± 0	650.0 ± 0	22.5 ± 4.5	8.1 ± 0	2,900 ± 432	1,730 ± 817
14	17.3 ± 0.3	7.7 ± 0.1	600.0 ± 0	24.5 ± 1.5	8.6 ± 0.2	4,300 ± 1,430	5,200 ± 1150
15	17.0 ± 0.5	7.5 ± 0.1	650.0 ± 150.0	66.0 ± 59.0	8.1 ± 0.5	3,470 ± 3,700	2,200 ± 1400
16	20.5 ± 1.5	7.7 ± 0	625.0 ± 25.0	43.0 ± 0	8.6 ± 0.1	1,000 ± 190	4,230 ± 490
17	21.0 ± 1.3	7.7 ± 0	640.0 ± 40.0	33.0 ± 0	8.9 ± 0.5	1,700 ± 920	5,030 ± 880

[a] ($\mu \pm \sigma$) = Mean colony forming units per 100 mililiters (CFU/100 ml) plus or minus one standard deviation.
[b] (ND) = no data collected.